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**LIQUEFIED METAL JET PROGRAM  
AUTOMATION AND ROBOTICS  
RESEARCH INSTITUTE (ARRI)**

**QUARTERLY TECHNICAL REPORT**

**REPORTING PERIOD: 15 January 1995  
THROUGH 15 April 1995**

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## **1.0 INTRODUCTION**

This report covers the period from 15 January 1995 through 15 April 1995. The Quarterly Technical Reports are organized by the Statement of Work (SOW) listed in Section 5.0 of the proposal. These are listed as follows:

- Reports and demonstration
- Equipment
- System test and experimentation
- Test coupon evaluation
- Technology transfer.

Test and evaluation of the no lead system has identified a problem with the nozzle design. Technical progress has been delayed resulting in a schedule slip of approximately 3 months. Multiple technical solutions are being pursued. Considerable resources are being placed on this problem. Many of these resources are being provided by non-ARPA funding. The design of the copper system is progressing very well, and the detailed design is 75 percent complete.

## **2.0 REPORTS AND DEMONSTRATION, SOW 5.1**

1. Weekly Progress Reports - Weekly progress reports are available.
2. Continued Demonstration of No lead System - Produced a limited number of crude single ball and straight line test coupons.
3. Program review was held on January 25, 1995 which included senior engineers from Texas Instruments Incorporated.

## **3.0 EQUIPMENT, SOW 5.2**

Major Program accomplishments during this reporting period include:

- Identified and incorporated improvements for no lead system reliability including the environmental chamber, and material contamination.
- Identified and designed several types of nozzles for evaluation
- Continued test copper and construction material compatibility.
- Completed conceptual design of copper system and subsystems.
- Completed approximately 75 percent of detailed design of copper fluidizer, droplet generator, target chamber, and system control.

### **3.1 Fluidizer, SOW 5.2.1**

The fluidizer module for the LMJ system converts the solid metal feedstock to liquid. The fluidizer module introduces the metal feedstock at a predetermined rate into a high temperature melt chamber. Propelling forces are required to drive the liquid metal jet at the predetermined velocity. The resulting liquefied metal is transitioned to the droplet generator for subsequent droplet formation.

The no lead fluidizer design continues to operate to specification and performs satisfactorily.

Detailed design of the copper fluidizer is about 90 percent complete. Many of the long lead items have been ordered.

### **3.2 Droplet Generator, SOW 5.2.2**

The proprietary droplet generator for the LMJ system accepts the liquefied metal from the fluidizer and provides the control of the instability required to excite the jet stream into a repeatable droplet formation. In addition, the droplets have a charge induced by an induction plate as they break away from the jet. A pulse signal is provided to charge the droplets so the trajectory through an electric field can be controlled. After being charged, the droplets will continue through an electrostatic deflection field, to impact the target at a precise location.

As mentioned in the last report, process reliability problems included environmental control in the test chamber and material contamination. Design changes have been incorporated to correct these problems.

The nozzle design, however, continues to provide reliability problems resulting in resources being redirected to identify potential solutions. A list of these options are shown in Table 1. Many of these resources are being provided by non-ARPA funds.

The detailed design of the copper droplet generator is 99 percent complete with the exception of the nozzle..

### **3.3 Jet/Droplet Stream, SOW 5.2.3**

A path for the droplets to be charged and deflected is provided in the design of the system. The path also provides for alternative atmospheres for experimentation.

Plexiglas has been a problem in testing because it holds moisture by absorption. This has required a change to stainless steel. The revised environmental chamber has been fabricated and installed.

The copper system conceptual design is complete and the detailed design is 90 percent complete. Detailed design is based on findings from the no lead system, and thermal analysis.

**Table 1. Phase II and III Nozzle Options in Evaluation**

ORIFICE OPTIONS	PRO	CON	STATUS
Bird Nozzle	1-2% work Easy change Good orifice finish	Expensive Long Lead Tin only 100 minimum	None planned for future use
EDM orifice	Easy No gaskets	Bad finish May not work We make parts	Not planned Hole too rough
Drill orifices	Easy Cheap No Gaskets	Rough hole May not work We make parts	In test
Use larger jeweled orifice	Cheap Good hole Better seal	sealing gaskets May not work We make parts 100 Minimum	On order Design in work
Use existing jewel orifice	Worked once cheap	sealing gaskets we make parts not repeatable	On hold, leaks repeatability
OTT Nozzle 316 SS punch	Work for ink Looks ok for TIn	May not work Copper unknown Made in Japan Long lead time	Prototype parts being made
Diamond wire Die orifice	Draws wire in 0.0005 "	High temp limits on Cu.	In test
Laser drilled orifice	Custom all materials	Bad holes	Not planned Bad finish Rough Hole
Modified GC Type orifice	Custom all materials	May not work No data on finish	Contacted vendors Investigating use

### 3.4 Target Chamber, SOW 5.2.4

The test coupons (i.e., samples) on which the experiment is run, reside in a fixture to hold the coupon and a chamber to provide for controlled inert atmosphere. This chamber provides controlled heat for coupon preheating, and provides for optical observation and instrumentation. In addition to the chamber, a precision motion control system to position the coupon for pattern writing has been designed, acquired and integrated into the LMJ system. A device to catch and collect the unwanted or "guttered" droplets is included in the coupon chamber.

The no lead target chamber is complete. Environmental control has been improved by changing the material construction from plexiglas to stainless steel. This eliminates leakage and moisture outgassing with the present structure. Operational reliability has been improved with this change.

Detailed design of the copper system target chamber is 50 percent complete.

### **3.5 System Control, SOW 5.2.5**

System control addresses all items necessary to control and monitor the process. Subtasks include hardware, software, integration for process control, environmental control, data acquisition, and safety. The system control include personal computers, programmable logic controller, data acquisition software, Computer Aided Design (CAD) data, Network Control program interface, and custom programming. Facility related subtasks includes, fume handling capabilities, safety systems, and thermal management equipment.

The system control computer for the no lead is complete. Some problems have been found with the speed of the XY table controller. Funds are available from other sources to upgrade the system controller. This table will be used for the copper system.

### **4.0 System Test and Evaluation, SOW 5.3**

Several system and subsystem tests have been conducted including:

- Nozzle tests
- Copper System construction materials.

### **5.0 Test Coupon Evaluation, SOW 5.4**

Evaluation of the test coupons will begin in the next reporting period.

### **6.0 Technology Transfer, SOW 5.5**

United States manufacturers continue to visit the lab for technology transfer. An industry day held at the Automation and Robotics Research Institute where the laboratory is located resulted in over 100 guest/visitors. Serious discussions are still being held with IBM, MPM, General Motors/Delco Electronics, Indium Corporation of America, and Alpha Metals.